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HEAT-EFFICIENT COMPOSITE WALL MATERIAL

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The effect of foam glass additives on the physicomechanical and thermophysical properties of construction ceramics is considered. The specifics of formation of a porous structure depending on the properties of source materials is investigated. A new glass-ceramic material with improved heat-insulating properties is obtained.

The need of modern construction industry for wall materials keeps growing, and the requirements imposed on these materials keep changing. Apart from increased requirements on thermal resistance, wall materials should have sufficiently high strength, satisfy the regulatory norms, and be environmentally clean, incombustible, and durable.

To solve these problems, a batch should contain technological additives capable of producing increased porosity while preserving strength parameters. It is possible to lower the density and increase the porosity of ceramic brick using the method of burning-out additives such as wood flour, sawdust, or husk. Research shows that on using this method fired bricks have numerous microcracks and weak contacts. This is responsible for the low strength of the product.

At present the construction materials industry is increasing the production of hollow bricks. Its thermotechnical efficiency is estimated based on the density of the finished brick, however, a study of hollow bricks in a climatic chamber established that their thermal conductivity does not follow the law of direct dependence of density and hollowness [1]. This is due to the fact that hollow articles possess so-called "bridges of cold"; in laying bricks the hollows get filled with mortar. When hollows are filled with mortar to a depth of 3 cm, the thermal conductivity of the brick grows by 32.8 – 43.7% [2]. This means that the use of hollow bricks does not fully solve the problem of heat-shielding wall structures.

In our study foam glass crumb was used as the pore-forming agent (RF patent No. 2231505). The effect of foam glass crumb on the main properties of composites was studied on experimental samples shaped as cubes, bars, and tiles by plastic molding.

The samples were prepared from clay from the Chibisovskoe deposit (Belgorod Region) and foam glass (produced by the Tekhnolog company in Belgorod). The clay considered is finely dispersed, contains a perceptible quantity of coarse fractions (up to 20%), and belongs to the group of clays with a high content of colorant oxides.

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According to x-ray structural analysis, the argillaceous material is represented by kaolinite with a small content of hydromica. Moreover, carbonates are identified in the rock considered. Quartz peaks in the diffraction pattern have the highest intensity. According to the classification, the argillaceous material from the Chibisovskoe deposit is of moderate plasticity (P-22) with a water mixing capacity of 18%.

The pretreatment of clay was carried out in accordance with the technological regulations; foam glass crumb was preliminarily milled and screened on sieves to obtain grains of size 0.5 – 1.0 and 1.0 – 2.0 mm. The initial composite mixtures (Table 1) were homogenized and moistened. Samples shaped as cubes (50×50 mm) were produced by plastic molding.

The molded samples were dried to a residual moisture of 1% and fired in a Silit furnace according to the following schedule: rate of temperature rise 2 – 3 K/min, 2-h exposure of samples in the furnace after reaching the required temperature. Slow cooling of samples was provided.

After each firing cycle we determined the water absorption, apparent density, shrinkage, compressive and bending strength, and phase composition using x-ray phase and microscopic analysis.

Samples of Chibisovskoe clay after firing at 1050°C had a compressive strength of 32 MPa, bending strength of 6.3 MPa, water absorption 13.3 %, total shrinkage 28.3%, and density 1.87 g/cm^3.

The results of studying the effect of foam glass crumb on the properties of ceramic materials are given in Table 2.

TABLE 1

Mixture	Weight content, %		Clay : foam glass crumb weight ratio
	clay	foam glass crumb	
1	100	0	1.0 : 0.0
2	80	20	4.0 : 1.0
3	60	40	1.5 : 1.0

TABLE 2

Mixture	Density, g/cm^3	Water absorption, %	Total shrinkage, %	Strength, MPa		Thermal conductivity W/(m · K)
				compressive	bending	
Firing temperature 950°C						
1	1.85	14.0	26.2	30	5.8	0.821
2	1.61	14.8	15.1	21	9.2	0.622
3	1.44	15.7	1.1	25	12.0	0.480
Firing temperature 1050°C						
1	1.87	13.3	28.3	32	6.3	0.821
2	1.60	15.0	15.5	24	14.0	0.620
3	1.46	16.2	0.5	27	14.8	0.498
Firing temperature 1150°C						
1	2.01	9.1	3.6	38	5.8	0.903
2	1.60	8.7	1.8	28	16.4	0.608
3	1.43	11.3	– 0.9	32	18.0	0.456

With the weight ratio between the components equal to 1.0 : 0.0, 4.0 : 1.0, and 1.5 : 1.0 the average density of articles decreases from 1.87 to 1.43 – 1.46 g/cm^3. The compressive strength decreases insignificantly to 24 MPa and then reaches its maximum value of 27 MPa. The bending strength grows more than twice compared to samples made of pure clay.

The physicomechanical properties of a porous material depend mainly on its phase composition and microstructure, i.e., on the size of pores, their homogeneity, and the thickness of walls between the pores. The total porosity of material containing 40% foam glass crumb is equal to 45%.

Due to the formation of needle-shaped crystals of mullite $3Al_2O_3 \cdot 2SiO_2$ in firing, a slight decrease in the compressive strength of samples is registered (mixtures 2 and 3) along a significant decrease in their average density (Fig. 1). This is validated by the results of x-ray phase and microscope analysis.

The service properties of material can be estimated based on the structural quality coefficient [3]:

$$A = \sigma_c / \rho^2,$$

where σ_c is the compressive strength, MPa, and ρ is the density of the material, g/cm^3.

A microscopic study of the polished sections (Fig. 2) of the new composite indicated that the structure of the material is largely homogeneous, where both sealed and communicating pores are observed. There is an insignificant spread in pore sizes: from fine spherical pores (0.08 – 0.15 mm) to larger irregular pores (0.35 – 0.65 mm); occasionally pores shaped as caverns are found. The rounded partitions between the pores consist of glass reinforced by mullite crystal of size ranging from 0.7 × 5.0 to 1.0 × 20.0 μm and under the effect of compressive stresses act as an arch, which has a positive effect on the strength of the composite. Furthermore, reinforcing the pore walls with new formations prevents the initiation and propagation of cracks.

The introduction of foam glass crumb improves the properties of products at the stage of drying and lowers shrinkage from 26 – 28 to 0.5 % and thermal conductivity from 0.82 to 0.48 W/(m · K).

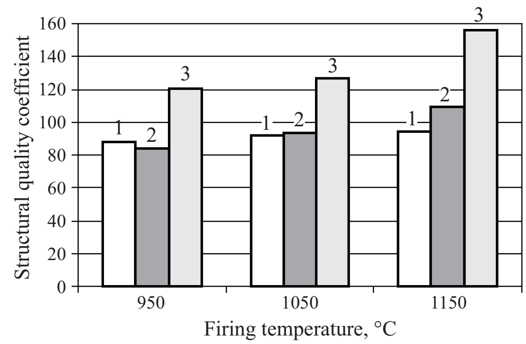

Fig. 1. The effect of the content of foam glass crumb and firing temperature on the structural quality coefficient in mixtures 1 – 3.

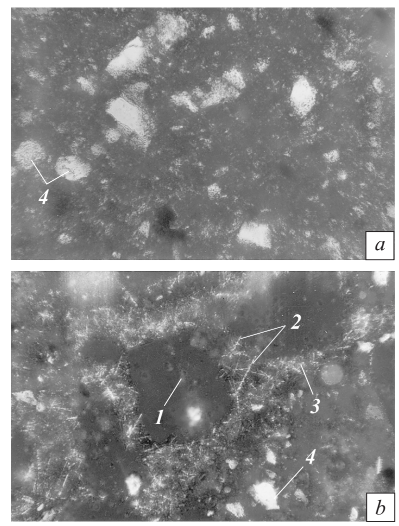

Fig. 2. Microphotos of samples after sintering at 1050°C in crossed nicols (× 320, transparent section, transmitted light): *a*) mixture 1; *b*) mixture 3; *1*) pore; *2*) mullite crystals; *3*) amorphous argillaceous material; *4*) quartz grains.

Thus, the use of foam glass crumb can produce heat-effective composite materials making it possible to lower the weight of walls in buildings while increasing the thermal resistivity of walls, which is a significant factor of energy saving in building maintenance.

The implementation of this technology implies using all types of waste generated in foam glass production.

REFERENCES

1. A. I. Anan'ev, "The problem of standardizing thermal engineering properties of ceramic brick and stone," *Stroit. Mater.*, No. 6, 17 (1993).
2. M. T. Gabidullin and A. V. Temlyakov, "Development of software for calculating thermal conductivity of enclosing structures based on efficient ceramic wall materials," in: *Proc. Intern. Congress "Contemporary Technologies in Construction Materials and Construction Industry", Part 2* [in Russian], Belgorod (2003), pp. 73 – 78.
3. M. I. Zeifman, *Production of Silicate Brick and Silicate Cellular Materials* [in Russian], Stroiizdat, Moscow (1990).